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TRANSMISSION LINE FAULTS DETECTION- A REVIEW

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ABSTRACT

Transmission lines consume a considerable amount of power. The necessity of power and its dependency has grown exponentially over the years. The void between limited production and tremendous demand has increased the focus on minimizing power losses. The losses like transmission loss range from the conjecture factors like physical or environmental losses to severe technical losses. The primary factors like reactive power and voltage deviation are significant in stretched conditions and long range transmission lines of powers. The subject of power transmission has always been an interest of researchers. A numerous methods have been developed to maximize the throughput of the systems. This paper reviews about different techniques for transmission fault detection.

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1. INTRODUCTION

In power distribution system, transmission lines are the most imperative part, as they play a key role in the transmission of power from generating station to load centres. Transmission lines function at distinctive voltage levels from 69kV to 765kV, and firmly interconnected for consistent operation. Various factors akin to de-regulated market environment, right of way, economics, environmental and clearance necessities have forced utilities to operate transmission lines near to operating limits. It is necessary to detect the faults; otherwise it will cause disturbances in the system which further led to extensive outages in the firmly interconnected system working within its limits. The design of transmission protection systems is in such a way so as to locate the fault location and segregate only the faulted part. It is a very challenging

task to identify and isolate the faults in order to have a very reliable transmission line protection.

Enhanced transmittable power, better power system stability, decreased transmission losses, decreased voltage drop, supple power-flow control, and improved voltage control are the economic and technical reasons following which series capacitors installation becomes very useful [1, 2, 3]. The part of line's inductive impedance is compensated by use of series capacitors. Further an improved voltage profile can be obtained by using series capacitor. Line inductance is reduced by series capacitors, which induce voltage (L di/dt) along the line [4]. Induced voltage superposes to the voltage imposed by the source. Voltage is increased if the line current leads the voltage and there occurs a voltage drop when the line current lags behind the line voltage. In this perspective, series capacitors reduce voltage boost and voltage drop as the line inductance is lesser for series compensated line as compared to that for uncompensated line.

When two or more than two conductors make contact with one another or with ground in three phase system, there occurs a fault which can be either a symmetrical fault or unsymmetrical fault [5]. Stresses are produced in the power system equipment due to excessive currents which are produced by faults. Further these faults cause grave damage on power system components. It is not only the equipment which is ill effected by the faults but the power quality also gets poor. So, in order to prevent the power system equipments from damages and to enhance the power quality, it becomes imperative to identify the type of fault and its location on the transmission line so that it can be removed with suitable means.

The problem of classifying the faults in the transmission line and then locating them has been a very difficult task. It is a foremost worry of the power industry to locate faults and classify them. Basically, protective relays, special control devices, protection software and recording devices are used to detect the fault and separate the faulty section from the system. It is very important to know all the information about the fault so as to detect it and then correct it as soon as possible. Presently, many researches are being carried to know about the techniques of fault location in distribution and transmission network which are based on artificial intelligence methods such as fuzzy-set theory, artificial neural networks, etc.

2. FAULTS IN TRANSMISSION LINES

To spread power from generating stations to remote load centres, transmission lines are used. Due to lightening, mis-operation, overload, short circuits, human errors, faulty equipment and aging, faults may occur on these lines. When fault occurs, the faulted phase voltage decreases and huge currents will flow which can burn out the components if not interrupted quickly.

In transmission lines with a three-phase power source, there are ten types of faults that can occur. The faults in the order of decreasing frequency of occurrence are: single-phase-to-ground faults (L-G), phase-to-phase faults (L-L), double-phase-to-ground faults (L-L-G), and a three-phase fault (3-ϕ).

Single line to ground faults (L-G) occur when one of the phases is shortened to the ground. During the fault the impedance, Z_{fag}, is not necessarily zero (bolted) but it might have a non-zero impedance but still much smaller than the line impedance. The magnitude of current in a faulty line rises significantly higher than the normal operative current while the voltage does not go through significant change in magnitude.

Table 1 Types of faults

Types of faults	**Symbol**	**% Occurrence**	**Severity**
Line to Ground	L-G	75-80%	Very less severe
Line to Line	L-L	10-15%	Less severe
Double Line to Ground	L-L-G	5-10%	Severe
Three phase	3-ф	2-5%	Very severe

Fault Location Techniques

- Technique based on fundamental-frequency voltages and currents, primarily on impedance measurement
- Technique based on high-frequency components of currents and voltages generated by faults
- Technique based on traveling-wave phenomenon
- Knowledge-based approaches.

Method based on the fundamental frequency currents and voltages at the line terminal in addition with the line parameters is the simplest way for determining the location of fault. It is generally considered that the impedance calculated for the faulted-line segment is a measure of the distance to fault. The Techniques belonging to this sort are simple and cheap for implementing. Performing such classification one has to take into account an availability of measurements: whether from one or both ends, and also whether complete measurements (voltage and current) or incomplete measurements (voltage or current) from a particular line end are utilized.

In traveling-wave methods, the current and voltage waves, traveling at the speed of light from the fault towards the line terminals are consider [25]. These methods are considered as very accurate, however, also as complex and costly for application, as requiring high sampling frequency.

3. LITERATURE REVIEW

It is very important to know the effect of series compensation on transmission voltages [4]. If the effect of series compensation on voltages is not known it will cause various operational problems such as high voltages and low voltages. Series compensation can cause low and high voltages due to different line loading conditions and the method by which the voltage control is adjusted. The voltage on the one side of the capacitor should be adequately controlled otherwise the other end of the capacitor cause voltage problems. When the line is lightly loaded, over-voltages can cause problems and in this case, series compensation will decrease voltage. But in case of heavily loaded lines, low voltages occur across the line, so series compensation will increase the voltage. Voltage collapse results from low voltages. And high voltages either cause flashover or decrease the life cycle of insulation and short circuits. Occasionally, series compensation is used to control power flow.

On directional relaying, current and voltage inversions takes place in a series compensated line [1]. A fault direction can be identified by fault identification scheme for series compensated line by change in magnitude of positive-sequence fault voltages and by change in phase of positive-sequence fault currents. Simulations is done with EMTDC/PSCAD and an algorithm is developed for series compensated line which uses fault current and voltage phasors to obtain the decisions. The process is tested for series compensated lines with the use of capacitor and without the use of

capacitor, fault resistance, change in source capacity, power-flow direction, fault inception angle, and for different system conditions.

Unsynchronized measurements by taking current and voltage signals of two ends to obtain the fault location algorithm of distributed parameter double-circuit series-compensated line was performed [6]. In this algorithm two subroutines are used for locating faults. Different formulas are obtained with the help of generalized fault-loop model. The distance of fault is independent of the parameters of the compensating bank and depends only on the location of compensating bank. The use of two-end signals measured asynchronously has been taken into consideration. ATP-EMTP is used for simulate different types of faults on double-circuit series compensated line.

A method to determine that whether the detected fault is located on a protected double-circuit line or exterior the line is described [7]. It is suitable for protection of double circuit uncompensated lines as well as for series-compensated lines. Only one-end measurements of phase currents are used. Simulation is done with ATP-EMTP software. A complete model of transmission line with the SCs & MOVs banks and measurement channels is developed. The proposed algorithm uses two subroutines: one for balanced lines and the other is used to detect unbalance in currents. Near 100% accurate fault classification is done for symmetrical parallel line and more than 85-95% in case when the line is unbalanced.

A method based on digital distance relaying for first-zone protection of series compensated double-circuit transmission lines has been presented in [8]. To estimate the fault distance, data from one end of the line is considered. The proposed method is independent on source impedance and fault current. Double circuit series compensated 400kV; 300km transmission line is simulated by using MATLAB/SIMULINK software and simulation results shows that the proposed method can be used to estimate accurate fault distance.

An algorithm that is applicable both to single and double-circuit series-compensated lines for finding fault location on series-compensated lines is proposed [9]. At both the ends of line, current differential relays are considered in order to find more refined solution for fault location. The proposed fault location technique can be achieved by incorporating differential protective relays with the fault locators. In this manner differential relays communication infrastructure is utilized. So, extra communication links are not required. Furthermore, differential relay utility is increased to a great extent.

In order to detach only faulted line, it is crucial to differentiate the faults zone precisely and indicate exact fault type with the aid of one end data only [10]. Transient current waves generated by faults contains distinct frequency bands and to capture two bands of frequencies from the transient current signal discrete wavelet transform db1 as a mother wavelet is used. Fault zone is determined by using the frequencies of these two bands. The mother wavelet Haar is used to select faulted phase. Faulted phase was classified by computing the average value of the coefficients of each current wave. A model signal is obtained using db6 as mother wavelet. The decision regarding fault to be external or internal was taken by determining the ratio of two energies for the modal signal.

A new scheme for the solution of the parallel transmission line protection problems which depends on the six phase line currents and three phase line voltages of the two parallel circuit lines at both ends is proposed [11]. Fault analysis is done by wavelet transform. And internal faults on double circuit line are recognized by comparing current phasors magnitudes of corresponding phases on each line. It is

shown that at different loading conditions each type of fault can be properly recognized.

For the power to be efficiently distributed to different locations, it is necessary to accurately detect and classify the different faults [12]. Active tripping of circuit breaker ensures the accurate protection of transmission line and circuit breakers tripping action depends on the current and voltages waveforms during the fault. For analysis of waveforms of current during fault, Discrete Wavelet Transform (DWT) is used. The evaluation of discrete wavelet analysis for identification and classification of faults on a transmission line network is done. According to energy level percentage, classification of faults has been done.

The use of wavelet transform for protecting the series compensated line by Current Differential pilot Relay (CDPR) is discussed [3]. Simulation results are obtained using MATLAB and analysis is done using db4 as mother wavelet. Fault classification is done by detecting different types of faults using wavelet based approach.

Probability based technique of Bayesian linear discrimination can also be used to differentiate between the different types of faults [13]. An adaptive wavelet algorithm (AWA) is used to generate the wavelets using probability based method of Bayesian linear discrimination. It is shown that adaptive wavelets can be used in the transmission lines of high speed protection system as analysis filters.

Power need to be transmitted from the power station to the load centres located far away [14]. So, the possibility of fault in the transmission lines is considerable. Here, comes the use of signal processing in the digital distance protection. Fourier transform and wavelet transforms are used for locating faults. Simulation is done with MATLAB/SIMULINK. Simulation result shows that wavelet method is more robust tool to locate the faults in the transmission lines. Further it is showed that both wavelet transform and Fourier transform methods can be used to find the characteristics of disrupt signals irrespective of the noise levels present.

The discrete wavelet analysis has been used for the protection of high speed EHV transmission line [15]. An algorithm for fault detection and classification based on discrete wavelet analysis has been presented. By comparing different wavelet coefficients of all three phase signals, type of fault is identified. And simulation is done using ATP-EMTP and MATLAB Wavelet toolbox. Such an algorithm is presented that is not dependent not only on fault location but also on fault inception angle and fault impedance. The algorithm is suitable, strong and quick and this is very prolific for EHV transmission line protection.

For the fault classification and boundary protection of series-compensated transmission lines, a new technique is proposed [2]. Different frequency bands of the wave of transient fault current are detected in order to have the suitable boundary protection. In order to amass the two frequency bands of transient fault current signal, db4 as a mother wavelet is used. Whether the fault is internal or external, it is determined by calculating the spectral energies of two bands of frequencies. Faulted phases are classified by calculating the average value of the wavelet coefficients of every current wave. A simple modal signal is obtained using the fault current values of three phases for all types of faults. Analysis of modal signal is done by using db4 as a mother wavelet, then detail 1 and detail 6 coefficients are calculated of the modal signal. To distinguish whether the fault is internal or external, the ratio of spectral energy is obtained and average values of d6 coefficients of three phase currents and ground current are obtained which is further applied to classify the type of fault.

A new approach for protection of TEED transmission lines and use wavelet transforms for accurate detection, classification and to locate faults in TEED transmission lines is presented [16]. The three phase currents at each terminal are decomposed at single level by using Bior2.2 as mother wavelet to obtain D1 detail coefficients. Then these detail coefficients at the three ends of TEED transmission line are added to obtain the resultant detail coefficients which are further compared with threshold values to detect and classify distinct types of faults in TEED transmission lines.

The use of Fuzzy logic and neural network for protection of double circuit series compensated transmission line is described [17]. Fuzzy logic and Neural Network are used for accurate decision making and to estimate the actual power system condition respectively, which increases the selectivity of protection system that further improves the reliability of power system. Effect of mutual zero-sequence coupling, series compensation and fault resistance is studied. The effect of the mutual coupling of parallel circuit and of series capacitor impedance on the relays accuracy depends on actual condition of power system. Ultimately, it is shown that with change in power system condition, the relay sensitivity is reduced to almost zero with decision making system of Fuzzy logic.

An impedance based calculation method to locate fault on transmission line is of immense importance [18]. Results get changed by changing line parameters. This is showed by carrying out the analysis of the two widely used methods in real faults. Most commonly used fault location methods are compared and their relative disadvantages and advantages are described. In this manner it becomes simple for the users to go for the most accurate method. Ultimately, it is shown that the two end methods are stronger than the one end methods as sensitivity to errors in two end methods is less as compared to one end methods.

Discrete Wavelet Transform (DWT) is used to extract the concealed factors from the fault signals by decomposition at distinctive levels [19]. Daubechies db6 wavelet is used for decomposition at single level. For ground faults a threshold is calculated to classify and detect the faulted phase. The fault location is determined by getting the local fault information, remote fault information and the length of transmission line. The system is considered with negligible fault resistance.

The protection scheme of double circuit transmission line based on artificial neural network (ANN) has been proposed [20]. Three stages are involved in this scheme to detect and classify different types of faults. Data from one end of the double circuit transmission line has been utilized to calculate the wavelet coefficients. The primary protection is provided to entire transmission line by using one end data only. For forward and backward adjacent transmission line, back up protection is provided. This technique improves the first zone reach setting up to 99% of the length of line for protection of transmission line.

A scheme based on wavelet transform for fault classification is proposed [21]. Currents samples from the three lines are used to calculate dWIabc. For different fault inception angles, different fault locations, and different fault distances and for different fault parameters simulation is done by EMTP software. It is shown that magnitude of wavelet transform is valuable to set threshold to discriminate between different types of faults hence to classify the faults.

An algorithm based on discrete wavelet transform is developed with C programming [22]. A 500-kv, 200km single line is simulated by using MATLAB. It is shown that as the fault resistance increases, the percentage error increases rapidly.

And when, the reactance of the circuit is considered to calculate the distance to fault, then the percentage error in the measurement of distance increases with increase in fault resistance.

A wavelet transform technique is developed to analyze power system disturbance such as transmission line faults with Biorthogonal and Haar wavelets [23]. In this paper, wavelet transform based approach, which is used to detect transmission line faults, is proposed. The coefficient of discrete approximation of the dyadic wavelet transform with different wavelets are used to be an index for transmission line fault detection and faulted – phase selection and select which wavelet is suitable for this application

4. CONCLUSION

Carrying out literature review is very significant in any research project as it clearly establishes the need of the work and the background development. It generates related queries regarding improvements in the study already done and allows unsolved problems to emerge and thus clearly define all boundaries regarding the development of the research project. Plenty of literature has been reviewed in connection with the detection of transmission line fault.

To improve the power quality of the transmission lines, compensation circuits are integrated. In order to increase the reliability of the system and reinstate the power supply in time, it is of immense important to classify and locate the fault rapidly and to isolate the faulty section precisely

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